Prediction of wrist arteriovenous fistula maturation with preoperative vein mapping with ultrasonography

Robert R. Mendes, MD,[a] Mark A. Farber, MD,[a] William A. Marston, MD,[a]
Lesley C. Dinwiddie, MSN, RN, FNP,[b] Blair A. Keagy, MD,[a] and **Steven J. Burnham, MD,[a]**
Chapel Hill, NC

Objective: **The purpose of this study was to determine whether the preoperative minimal cephalic vein size in the forearm was predictive of successful wrist fistula maturation to a functional hemodialysis access.**
Methods: **Forty-four consecutive patients underwent evaluation before surgery with ultrasound scan imaging to map the entire cephalic vein in preparation for the construction of an arteriovenous fistula at the wrist. Measurements of the vein diameter were obtained from the ultrasound scan images at eight representative sites. Patients were clinically followed to determine maturation of the fistula to provide a functional hemodialysis access. The smallest diameter of the cephalic vein then was used as a preoperative predictor of fistula maturation.**
Results: **Successful maturation of the arteriovenous fistula was achieved in 22 of the procedures (50%). Cephalic veins with a minimal diameter of 2.0 mm or less were used for anastamosis in 19 patients (43%), and three of these procedures (16%) led to a functional access site. The remaining 25 patients (57%) had minimal cephalic vein diameters greater than 2.0 mm, producing a successful maturation in 19 of the fistula creations (76%). A significantly higher rate of successful fistula maturation in those patients with a preoperative minimal cephalic vein size greater than 2.0 mm was realized ($P = .0002$, χ^2 test, with Yates correction for continuity).**
Conclusion: **In patients with a minimal cephalic vein size of 2.0 mm or less, a procedure other than wrist fistula should be considered for optimization of dialysis access. (J Vasc Surg 2002;36:460-3.)**

The number of patients in the United States needing chronic hemodialysis is steadily approaching 300,000, and care for these patients has a significant economic impact.[1] Currently, almost one fifth of the healthcare cost for hemodialysis is used to maintain access patency. The creation and maintenance of uninterrupted hemodialysis access would optimally reduce patient morbidity and costs.

Several studies have shown that arteriovenous fistulae (AVF) have the highest functional primary and secondary patency rates when compared with prosthetic access.[2-4] The National Kidney Foundation's Dialysis Outcomes Quality Initiative had set goals that a minimum of 50% of all new hemodialysis accesses be of this type.[5,6] However, some investigators have reported that AVF maturation rates vary widely, from 25% to 80%, arguing that the high early failure rate of the autogenous AVF brings the overall patency down to comparable rates with prosthetic grafts.[7]

From the Department of Surgery, Division of Vascular Surgery,[a] and the Department of Medicine, Division of Nephrology,[b] University of North Carolina at Chapel Hill School of Medicine.
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Reprint requests: Dr Robert R. Mendes, UNC, Division of Vascular Surgery, 210 Burnett-Womack Bldg, CB # 7212, Chapel Hill, NC, 27599-7212 (e-mail: bobbymendes@yahoo.com).

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Currently, few clinical pathways are used, in addition to the physical examination, that predict success of fistula maturation for AVF construction. An algorithm that would reliably predict which veins are likely to yield a functional hemodialysis fistula would maximize the number of patients receiving AVF and reduce the number of unnecessary attempts at fistulas that are likely to fail. Ultrasound scan imaging has been described as a technique to map veins before lower extremity bypass to help determine vessel suitability and for use in AVF construction.[8,9] This study was undertaken to determine whether the preoperative minimal cephalic vein size in the forearm was predictive of successful wrist fistula maturation to a functional hemodialysis access.

METHODS

A study of 48 consecutive patients seen by the Division of Vascular Surgery at the University of North Carolina at Chapel Hill School of Medicine was conducted. All patients were determined to be candidates for the construction of an AVF at the wrist on the basis of the criteria in the Table.

Each limb was examined with the patient in a reclined position and the arm dependent. A tourniquet was not used to enhance the vein size. With ultrasound scan imaging (ATL HDI 3000, Accuson Sequoia, or Accuson XP-10 with 5-MHz, 7-MHz, or 10-MHz scanning probes), the cephalic vein was identified at the wrist and followed proximally through its entire course to the proximal upper arm. Veins were assessed for compressibility, diameter, areas of stenosis, anatomic variation, thickness, and depth below

the skin. Measurements of the vein diameter were recorded from the ultrasound scan images at eight representative sites: the wrist, distal forearm, mid forearm, proximal forearm, antecubital fossa, distal upper arm, mid upper arm, and proximal upper arm (Fig 1). Quality analysis of the ultrasound scan equipment with an ultrasound phantom is performed every 6 months to ensure accuracy of the measurements. Patients were excluded from the study if the cephalic vein was unable to be visualized with ultrasound scan imaging techniques.

The access procedures were performed with local or regional anesthesia on an outpatient status. All cephalic veins were divided distally and sewn end to side to the radial artery with running polypropylene suture. The technique of Cimino fistula creation has been described elsewhere.[10] Use of a tourniquet during the construction of the radial-cephalic fistula was left to the discretion of the operating surgeon but was not routinely used.

Patients were closely followed to determine the incidence of complications and to follow maturation of the AVF. *Maturation* was defined as the ability to provide ongoing functional hemodialysis at 3 months from the access procedure. A nephrologist determined when the fistula was ready for an attempt at cannulation. An experienced dialysis nurse attempted initial cannulation of the fistula; if unsuccessful, the fistula then was evaluated by the vascular surgeons at the University of North Carolina.

The smallest diameter of the cephalic vein from the wrist to the proximal upper arm then was used as a preoperative predictor of fistula maturation; location along the vein course was not used as a determining factor for success. Intraoperative correlation of vein size was not performed because the location of the smallest cephalic vein diameter was often not at the level of the wrist. Patients were excluded from the study if they were lost to follow-up or died within 3 months after surgery.

RESULTS

Between February 1999 and May 2001, 48 consecutive patients eligible for wrist fistula creation were enrolled in the study. During this study period, approximately 60% of all dialysis access procedures were performed without the use of synthetic material (wrist fistulas, brachial–cephalic fistulas, basillic transposition, etc) and 25% of all dialysis access procedures were wrist fistulas.

One patient had inadequate preoperative vein mapping and was removed from the study. The success of ultrasound scan vein mapping was 98%. Three other patients were subsequently removed for the following reasons: one died 6 weeks after surgery and two were lost to follow-up. The remaining 44 patients had a mean age of 55.5 years (range, 16 to 89 years), and 79.5% were male.

Two perioperative complications were identified. One patient had significant pain in the hand after surgery and was diagnosed with nerve compression from edema but was successfully treated with cortisone injections. The other patient had a bradycardic episode on the operative table before incision, and the procedure was aborted; however, the patient did undergo the procedure 4 weeks later without complication.

Clinical criteria for selection of upper extremity AVF creation at wrist

Venous examination
Visible cephalic vein after placement of tourniquet
Vein courses superficially
Absence of tortuous vein
Arterial examination
Easily palpable radial pulse
Patency of palmar arch (Allen's test)
Absence of significant pressure differential $\geq$ 20 mm Hg between arms

Successful maturation of the AVF was achieved in 22 of the procedures (50%). Cephalic veins with a minimal diameter of 2.0 mm or less were used for anastomosis in 19 patients (43%), and three of these procedures (16%) led to a functional access site. The remaining 25 patients (57%) had minimal cephalic vein diameters greater than 2.0 mm, producing a successful maturation in 19 of the fistula creations (76%; Fig 2). A significantly higher percentage of fistulae matured in those patients with a preoperative minimal cephalic vein size greater than 2.0 mm ($P = .0002$, χ^2 test, with Yates correction for continuity). Three cephalic veins with a diameter of 2.0 mm or less matured and were identified to have minimal diameters of 1.2, 1.8, and 2.0 mm. Six patients with veins greater than 2.0 mm in diameter had failure, with minimal diameters ranging from 2.1 to 3.2 mm in size.

DISCUSSION

Surgeons performing hemodialysis access for the dialysis population are under great pressure to perform fistulae rather than prosthetic arteriovenous accesses given the improved function of fistulae if they mature. However, the construction of an AVF is not the objective, rather the construction of a durable access to provide dialysis should be the goal. Many surgeons are noting a decreased rate of maturation as the number of AVF procedures increase. Preoperative techniques to guide the surgeon in choosing the optimal site for fistula construction or to determine when the patient is a poor candidate for fistula construction have not been well described.

Silva et al[8] provided criteria in both venous and arterial preoperative evaluation. Arterial inflow was considered satisfactory if there was an absence of pressure gradient between arms, a patent palmar arch, and an arterial lumen greater than 2.0 mm. Venous outflow was deemed satisfactory if the venous lumen was greater than or equal to 2.5 mm, but no prospective evaluation of this recommendation was performed. Berman and Gentile[11] evaluated the impact of secondary procedures on autogenous AVF. They determined that aggressive assessment followed by secondary procedures on immature or failing fistulas improved accomplishing or maintaining a functional AVF by 10% and is thus warranted.

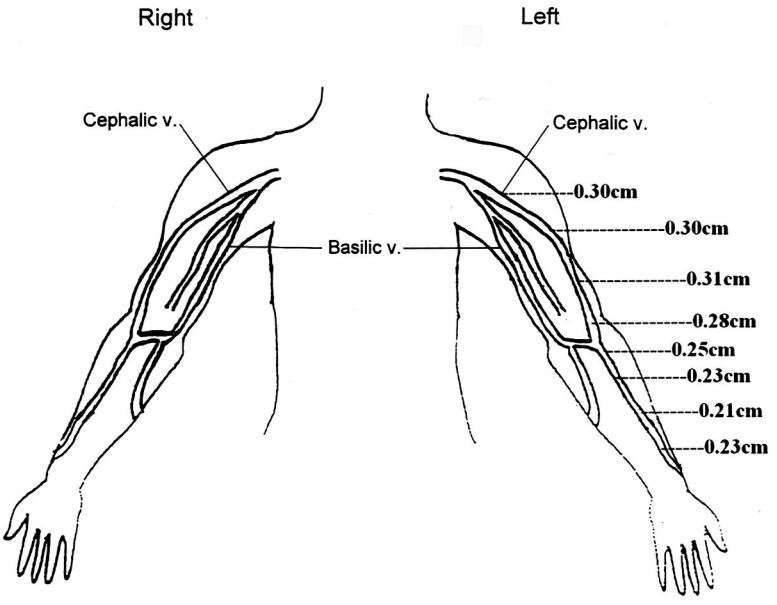

Fig 1. Upper extremity vein mapping, depicting eight representative measurement sites of the cephalic vein.

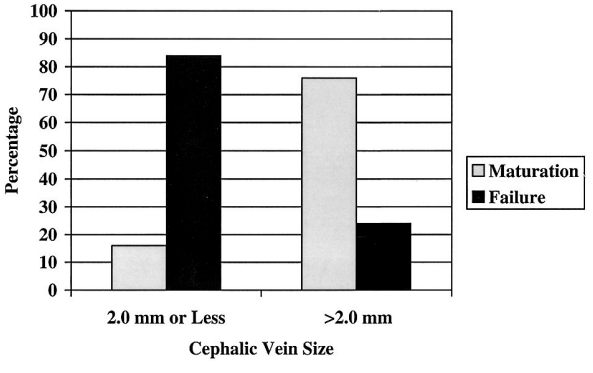

Fig 2. Outcome rates for minimal cephalic vein size.

As shown with this study, preoperative ultrasound scan vein mapping of patients can predict the successful maturation of an AVF at the wrist. Fistulas with cephalic veins greater than 2.0 mm proceed to a functional dialysis access in 76% of the cases, and use of cephalic veins with diameters 2.0 mm or less will be functional only 16% of the time. Although several investigators recommend tourniquets to aid in ultrasound scan vein mapping, in this study we elected not to use this technique. It is difficult to standardize the amount of pressure applied with a tourniquet, particularly at low pressures and in arms of varying circumference. Patient comfort was also a factor because the duration of the examination could last up to 45 minutes, depending on the anatomy of the cephalic vein (depth of vein, course variations in runoff, etc) and other arm veins to be examined.

Preoperative ultrasound scan also provides other useful information with respect to compressibility, vein thickness, anatomic variation, and depth below the skin. These factors can all aid in the clinical decision to create a wrist fistula, and further study on their correlation to fistula maturation is warranted.

CONCLUSION

Routine preoperative ultrasound scan vein mapping is useful in evaluation of patients in need of hemodialysis access. Patients with a minimal cephalic vein diameter of larger than 2 mm had a significantly higher incidence rate of functional fistula maturation. In patients with a minimal cephalic vein size of 2.0 mm or less in the forearm, an alternative fistula site or an alternative procedure (eg, a prosthetic forearm loop graft) should be considered to optimize dialysis access.

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DISCUSSION

Dr David L. Cull (Greenville, SC). Dr Mendes and his colleagues report a series of 44 patients who were deemed candidates for creation of a radiocephalic fistula based on physical examination who underwent preoperative vein mapping with duplex ultrasonography. They showed that in patients who had a minimum cephalic vein diameter of 2 mm or less, only 16% of the fistulae had matured by 3 months. In those patients who had minimal cephalic vein diameter of greater than 2 mm, 76% of the fistulae matured. They conclude that an alternative fistula site or arteriovenous graft placement should be considered in patients with cephalic veins of 2 mm or less.

I have the following questions for the authors. In addition to vein size, female gender, diabetes mellitus, and patient age have been shown to adversely affect the maturation rates of radiocephalic fistulae. Did you look at these other factors in your patients as to exclude their effect on your maturation rate? In the group of patients who had veins less than 2 mm, were there any differences in those patients who had fistulae that matured compared to those patients who had fistulae that failed to mature?

My next questions relate to your definition of successful fistula maturation. In your study, a fistula that was unable to sustain a patient on dialysis by 3 months was considered a failure. Is 3 months an adequate time to determine whether a fistula will mature? Also, did you evaluate the fistula that failed to mature to determine if they could be salvaged with revision? A recent article published by Berman in the *Journal of Vascular Surgery* showed that a number of unmatured fistulae can be salvaged with surgical revision. In short, do you think if you had waited longer and aggressively evaluated and revised the unmatured fistulae in your study that you could have increased the maturation rate for the smaller fistulae?

Finally, your conclusion infers that a 16% maturation rate for radiocephalic fistulae is unacceptable and arteriovenous graft placement is preferable. The exalted status of the radiocephalic fistula among surgeons and nephrologists is derived from the fact that its creation is associated with very low morbidity and its long-term patency is excellent in those patients who develop a mature fistula. Since the morbidity is so low and the potential benefits of a mature radiocephalic fistula are so great, what would you consider to be an acceptable maturation rate for the radiocephalic fistula?

I wish to thank the authors for providing a copy of their manuscript for my review in a timely fashion, and I wish to thank the program committee for allowing me to discuss this paper.

Dr Robert R. Mendes. In regard to your first question pertaining to the factors of gender, diabetes, and age and their affect on fistula maturation, I agree some studies have shown these factors can influence the outcome of these procedures. We evaluated these factors in our patient group and we did not find any significant relationship with race, gender, age, or diabetes to fistula maturation.

Next you asked whether our time for maturation was adequate. Our patients are evaluated by their nephrologist, and most attempt to use the fistula at approximately 6 weeks postoperatively. If by 3 months the fistula has failed to mature, we begin some type of diagnostic intervention. In our patient population of those that failed to mature by 3 months, none matured after that time.

In regard to whether we evaluate fistulae for revision, yes, we do. We revised three fistulae, two with veins < 2 mm and one had a diameter > 2 mm. All three of our revisions were unsuccessful. In light of the current data, I do think we should become more aggressive in our attempts at fistula revision for those with smallest vein diameters greater than 2 mm.

Finally, you ask what I consider an acceptable maturation rate. In our practice, we use 2 mm as our cutoff for attempts at wrist fistulae. However, if a patient has a vein size of say 1.8 to 2.2 mm and a favorable clinical exam, we may attempt the procedure, with the knowledge that the fistula has a significantly reduced chance of maturation.

Dr Paul Citrin (Wesley Chapel, Fla). Did you measure your veins at the time of surgery with a garret dilator or any similar device to see exactly what size they were?

Dr Mendes. No, we did not. Most of the areas of smallest diameter were not in the operative field. We relied on our ultrasound measurements for the purpose of this study.